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CENTER FOR NAVAL ANALYSES

Operations Evaluation Group
Study 250

VISION IN AIR SEA RESCUE SEARCH

February 1946
(Retyped November 1971)

E.S. Lamar

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SUMMARY

The subject report is an analysis of the data of reference (a) made in the light of the theoretical considerations of reference (b). The report has the twofold purpose of presenting a more complete analysis of the data than is possible without some basic search theory, and of obtaining from the data more reliable values of the parameters occurring in the theory than those derived from operations under combat conditions. The report deals with the ranges at which various targets can be seen under different conditions as regards such things as sun; sea; cloud and haze; and with the probabilities that these targets will be seen. The results obtained are in good agreement with theory and consequently with those laboratory measurements which constitute part of the basis for the theory. The results provide information on which to base procedure to be employed and force requirements for a given search task. The conclusions are in general agreement with those presented in reference (a) but differ from them in certain minor details.

CONCLUSIONS

1. The range at which a given target can be seen in daylight is largely determined by its apparent area and contrast, its shape and color being of only minor importance.

2. The contrast of a given target is dependent upon the altitude and relative bearing of the sun, and upon atmospheric haze. No effect of cloud cover or sea state was detected for cloud covers ranging from 0.2 to 0.7 inclusive or for sea states ranging from 2 to 4 inclusive. Further trials are needed for sea states in excess of 4.

3. Daylight air-sea rescue search is most effective between mid-morning and mid-afternoon, i.e., when the sun's altitude exceeds 30°.

4. Parallel sweep search is more effective if the successive legs are up or down sun than if they are across sun as recommended in reference (a). For the up sun sweep, the lookout assignment should include one man in the tail gun position in the aircraft.

5. The lookout assignment should provide for uniform coverage of the forward 180° of azimuth, with an additional lookout in the tail gun position to cover the aft 45° during the up sun runs.

6. Scanning should be carried out almost entirely along a line a few degrees below the horizon with only short glimpses closer in. This results from the fact that the "corner of the eye" can be relied upon to sight most of the targets near the aircraft.

7. In the present stage of the art, naked eye search is more effective than binocular search from aircraft in daylight.

8. The "Learned signalling mirror" can be seen much farther from an aircraft than the aircraft can be seen from a life raft, provided of course that the sun is not obscured by overcast. Hence, making contact with the aircraft depends upon the abilities of the life raft occupant as regards search and skill in using the mirror. The advantage of training and drill in the use of this excellent piece of equipment cannot be overemphasized.

9. For sea states of 6 or less, the average range of pick-up of Dye Marker - Life Jacket Packet, is more affected by time in the water than by sea state. Further trials are needed for sea states in excess of 6. This average range reaches its maximum value about 15 minutes after the packet is in the water. At the end of about an hour, the average range drops to about half its maximum value.

10. Since the use of mirrors, dye markers and other means of making contact requires that the occupant of the life raft first detect the search craft, aircraft for air-sea rescue operations should be made as conspiciuous as possible. For daylight search this is best accomplished by painting the aircraft black.

11. Naval or other personnel in life rafts should scan uniformly over a line a few degrees above the horizon. Training in scanning and in the use of mirrors, dye markers and other means of making contact is of the greatest importance for all prospective subjects of air-sea rescue search.

12. The quantitative conclusions concerning the ranges at which various targets can be seen and the probabilities that they will be seen with any given parallel sweep spacing are given in the appendix.

APPENDIX A

APPENDIX A

I. VISUAL SEARCH THEORY IN BRIEF

The theory of visual search, described in detail in reference (b) is based on the idea, first proposed by Craik (c), that the chance of seeing a target in unit time depends upon the angular size of the retinal region within which it can be seen. The form of the function depends upon the type scan employed in search, i.e., line scan, area scan or something in between. The form of this function is known and will be discussed in this section.

The retinal region mentioned above is described in terms of the maximum angular separation of the target from the line of sight, within which the target can be seen. This angle, θ_0, depends primarily upon the angular size of tne target, and the brightness contrast of the target against its background. The effects of such quantities as target shape and color, on the off axis angle θ_0, can be neglected in most cases. The angular size of the target is described in terms of the visual angle α, i.e., the angular diameter of a circle having the same area as the target. The brightness contrast is defined as the difference in brightness between the target and its immediate background, divided by the effective background brightness, this brightness being the one for which the eye is adapted.

These three variables, contrast C; off axis angle θ_0, and visual angle α are connected by the following equation

$$C = 1.75\sqrt{\theta_0} + 19\,\theta_0/\alpha^2 \qquad (1)$$

which holds over quite wide limits. It does not hold for $\theta_0 > 90^0$ because the average observer cannot see "out of the corner of his eye" more than 90^0 from the most direct line of sight. It does not hold for $\theta_0 < 0.8^0$ because the retina is fairly uniform in sensitivity over this region. This value of 0.8^0 is about the angular radius of the fovea, the most sensitive part of the eye for daylight vision. The constants in equation (1) are appropriate for the following set of units: contrast in percent, θ_0 in degrees and α in minutes.

In order to use equation (1) in any given case, it is necessary to replace the variables α and C by those which occur in the operational situation. The angle α can be expressed in terms of target area, and the range at which the target is viewed. These are two cases which must be considered, one in which the target is viewed more or less normally so that the real and apparent areas are the same and the other in which the real area must be projected normal to the line of sight. The latter case is exemplified by targets such as ship's wakes and dye markers which are more or less flat on the sea surface. The target contrast is a function of the near contrast C_0, i.e., the contrast in the absence of haze, the meteorological visibility V, and the target range R. In these terms equation (1) becomes for Case I

$$C_0\,E(R,V) = 1.75\sqrt{\theta_0} + 46.4\,\theta_0 R^2/A, \qquad (2)$$

$$\text{where } E(R,V) = \exp\left\{-3.44\,R/V\right\},$$

and for Case II

$$C_o\ E(R,V) = 1.75\sqrt{\theta_o} + 2.79\,(10^5)\ \theta_o R^3/Ah \tag{3}$$

where R and V are in nautical miles, A is the target area in square feet and h is the aircraft altitude in feet.

The foveal or maximum range R_m is obtained by setting $\theta_o = 0.8^o$, its value for foveal vision. R_m is interpreted as the range to be expected if one knows exactly where to look for the target. The maximum range equation, in a form convenient for plotting, is for Case I

$$V = 1.49R_m/\log_{10}\left[C_oA_o/(36.9R_m^2 + 1.57A_o)\right] \tag{5}$$

and for Case II

$$\frac{V}{\sqrt[3]{h}} = 1.49\left(\frac{R_m}{\sqrt[3]{h}}\right)\Big/\log_{10}\left[C_oA_o\ (2.26(10^5)R_m^3/n + 1.57A_o)\right] \tag{6}$$

The most convenient operational variables to use in expressing θ_o are R/R_m, R_m/V, and C_o. In these terms

$$\theta_o = F\left\{\sqrt{\frac{F+1}{G}} - 1\right\}^2 \tag{7}$$

where

$$F = 0.49(R_m/R)^{2n}/(C_oE(R_{m_1}V) - 1.565)^2$$

and

$$G = 0.8C_oE(R_1V)\,(R_m/R)^n/\,(C_oE(R_{m_1}V) - 1.565)$$

The constant n has the value 2 for Case I and 3 for Case II.

As regards the chance of seeing a given target in unit time, there are two limiting cases to consider, one in which the target can be expected to appear anywhere along a given line and the other in which the target can be expected to appear anywhere within a given area. For the line case, uniform scan along the given line is recommended and the probability k of seeing the target in unit time is a proportional to θ_o/Θ where Θ is the azimuth over which the search is carried out. For the area case, k is proportional to θ_o^2/Ω where Ω is the solid angle subtended by the area to be searched. The constant of proportionality can be determined, in the line scan case, from existing laboratory data (reference (c)) so that

$$K = 1.2\ \theta_o/\Theta \tag{8}$$

for time expressed in seconds.

We are now in a position to consider an actual operational example. Let an aircraft approach a target with a speed large compared to that of the target. We are interested in the probability that the target will be seen as the aircraft passes it. We will refer everything to a coordinate system fixed with respect to the aircraft. The y coordinate is parallel to the aircraft track and the x coordinate normal to it. Time is taken as zero where y is zero. Let P be the probability of seeing the target and Q the probability of not seeing it. Then $P + Q = 1$ and $dP = -dQ$. The probability of seeing the target in time dt is kdt and the probability dP of seeing the target first in dt is

$$dP = Q\, k\, dt = -dQ \tag{9}$$

the factor Q being necessary to eliminate the possibility that the target has been seen already.

Solving equation (9) and putting in the boundary conditions

$$P = 1 - \exp\left\{ - \int_t^{\infty} k dt \right\} \tag{10}$$

Now k is a function of θ_o from equation (8). For a given target in a given meteorological visibility, θ_o is a function of R/R_m only from equation (7). The quantity $dt = 3600\, dy/v$ where v is the aircraft speed in knots y is in nautical miles and dt is in seconds. Hence, making the various substitutions,

$$Q = \exp\left\{ - \left[4400 R_m / V\Theta\right] \int_{y/R_m}^{\infty} \theta_o\, d(y/R_m) \right\} \tag{11}$$

$$P = 1 - Q$$

It is to be pointed out that equation (11) assumes search for positive values of y only. For a given number of lookouts the result is the same as if negative values of y were included since changing the track length over which search is carried out requires changing Θ by the same factor.

Equation (11) is usually integrated graphically from $y/R_m = 0$ to $y/R_m = \infty$, i.e., for search over the forward 180° of azimuth. The resulting values of P obtained for the various values of x are then plotted as a function of x to give a so called lateral range curve. If plotted to both sides of track, the area under the lateral range curve is the effective path swept, i.e., the path such that the number of targets seen is the same as though all targets within and none outside this path were seen. The path swept is the quantity which determines the force requirements for any given search task.

The above, in brief, is the theory of visual search from aircraft as presented in more detail in reference (b). In the sections of this appendix which follow, the data of reference (a) are examined in the light of the theory. It is to be hoped that as this examination progresses the significance of the theory and its potentialities for the solution of practical problems in naval operations will become more apparent.

II. LIFE RAFTS

In considering search for life raft we are interested ultimately in the probability of sighting a raft for any given spacing of parallel sweeps or equivalently, the sweep spacing and hence, the force requirements for a given probability that the search for a life raft will be successful. For determining this probability we have at our disposal the data of reference (a) and the theory described in brief in Section I. The sightings of life rafts presented in reference (a) are of three kinds; assisted sightings in which the raft is known to be at one end of a visible dye marker; unassisted sightings in which the raft is known to be near the aircraft track, and simulated search sightings in which the raft is known to be in the area searched. The unknown, parameters in equation (7) which determine θ_o and hence, the probability of sighting are R_m and C_o. These two parameters and the way in which they depend upon such quantities as sea state, cloud cover, and altitude and relative bearing of the sun can best be determined from data of the first type in which R_m is measured directly. This will now be done.

Before values of the various parameters can be obtained from the maximum range data, it is necessary to know the case to which the target belongs. Reference to equation (5) shows that if the target belongs to Case I, R_m is independent of altitude. On the other hand, if the target belongs to Case II, equation (6) indicates that R_m does depend upon the altitude of the search aircraft. With the Mk II raft, assisted range data is presented in reference (a) for four different altitudes, 500, 1500, 2000, and 3000 feet. If it can be assumed that to first approximation, the effects of the other operational variables average out, these data can be employed to determine the case to which the target belongs. The averages obtained for R_m at the four altitudes were 1.55, 1.88, 1.55, and 1.77 nautical miles, respectively. Since no definite trend is shown, it is concluded that manned life rafts belong to Case I. This conclusion is further substantiated by data taken with the pararaft. There two altitudes, 500 and 1000 feet, gave average values for R_m of 1.57 and 1.55 nautical miles, respectively.

Because of the fact that the ranges at which life rafts can be seen are relatively short it is worthwhile to make a simplification which allows the elimination of one variable. From equation (2) and equation (3) it can be seen that if the meteorological visibility V is always large compared to the range R, the effect of atmospheric haze, as described by the meteorological visibility, can be neglected. Here again data taken with the Mark II raft provide means of determining the importance of atmospheric haze. The data taken with meteorological visibilities of 4.5 and 8 nautical miles yielded average values for R_m of 1.68 and 1.52 nautical miles, respectively. Not only are these ranges approximately the same, but the higher meteorological visibility yields the smaller range. It is clear, therefore, that within the fluctuations to be expected from the test data, the effect of atmospheric haze can be neglected for the Mark II raft provided the meteorological visibility exceeds 4.5 nautical miles. Since the ranges for the other rafts are of the same order of magnitude, atmospheric haze is neglected in the analysis of life raft sightings.

In the absence of haze, two life rafts differing only in size and number of men aboard should be seen at the visual angle α. In other words, the maximum ranges for the various rafts should be proportional to the diameters of the circles having the same areas as the targets. Before this can be tested some estimate of the target area must be made. This has been done and the steps in the process are presented in

Table I. Maximum range data was available from reference (a) for the Mk VII, the Mk II and the pararaft. The averages obtained for these three rafts were 2.2, 1.6, and 1.2 nautical miles, respectively. When each is divided by the appropriate target diameter listed in Table I, the ratios obtained are 0.49, 0.49, and 0.44, respectively. Since there is no definite trend apparent it is concluded that, in the absence of hazes, two life rafts differing only in size and number of men aboard can be seen at the same visual angle α. In reference (a) preliminary test of the proposition just stated was made with the unassisted range data. With these data, the dispersion was too great to show the effect. Having found an equivalence among the various rafts, it is possible to reduce all maximum range data to the same scale and thus increase the quantity of data available for investigating the effects of other operational variables. This has been done the scale selected being that of the Mk VII raft.

Table 1

Raft	Mk VII	Mk IV	Mk II	Pararaft
Length (feet)	12	9.17	7.5	5.5
Width (feet)	5.25	5.00	4.0	3.3
Freeboard-overall (inches)	16	15.25	13	12
Freeboard-water (inches-estimated)	8	7,62	6,5	6.0
Ave freeboard area (sq.ft.)	5.8	5.0	3.1	2.2
Ave man area (sq.ft.-estimated)	10.0	8.8	5.6	3.6
Effective target area (sq.ft.)	15.8	13.8	8.7	5.8
Diameter of eq. circle (ft.)	4.5	4.2	3.3	2.7

Test for the effect of cloud cover on the maximum sighting range was carried out for 0.2, 0.3, 0.4, 0.5, 0.6 and 0.7 cloud. The number of runs available were 45, 11, 14, 4, 2 and 21 respectively. These yielded average values for R_m of 2.0, 2.6, 2.1, 1.7, 1.4 and 2.2 nautical miles, respectively. Except for relatively large fluctuations in these values which are based on so few runs that the effects of the other variables do not average out, no effect of cloud cover is apparent.

Except for one run in sea state 3, all the maximum range runs were for sea states 2 or 4. Of the former there were 53 which gave an average value for R_m of 2.1 nautical miles. Of the latter there were 44 which also yielded 2.1 nautical miles. Over this range of sea states, therefore, no effect is apparent. Further trials are needed for sea states in excess of 4.

The altitude and relative bearing of the sun have a rather marked effect upon the maximum sighting range, presumably through their influence on the intrinsic contrast. The maximum sighting range runs, taken at 8 different bearings relative to the sun divide themselves rather naturally into two groups, those for which the altitude of the sun is greater than 30^o and those for which it is less. The average values of R_m for these two groups are presented in Figure 1. Curve A is for altitudes equal to or greater than 30^o and curve B for less. These curves show the same trends as those presented in reference (a) for the unassisted sightings. It is believed that the effects of sun's altitude and relative bearing on the intrinsic contrast are twofold. First, the relative illuminations of target and background and

hence, the brightness difference depend upon these two variables. The fact that the B curve of Figure 1 is everywhere inside the A one indicated that the sun's altitude is the chief factor contributing to this effect. Second, the sun, shining on part of the retina, constitutes a source of glare which alters the level of adaptation and hence, the effective background brightness. This effect is indicated quite strongly by the dimple in the B curve for the up sun direction. If the effective area of the Mark VII raft is substituted in Equation (5), remembering that V can be considered infinite, the intrinsic contrast can be computed from the ranges given in Figure 1. This has been done and the results are presented in Figure 2. The A and B designations are as in Figure 1.

In many of the maximum sighting range runs, one observer employed 7.50 binoculars. The average values of R_m so obtained are presented in curve C of Figure 1. It is surprising to note that the gain in range over the naked eye is almost negligible. Although there is , undoubtedly, some reduction in contrast because of light scattering within the binoculars it seems improbable that this could account for the results observed. It seems more likely that vibration of the aircraft is the chief source of the difficulty. Whatever the cause, the fact remains that the increase in maximum range produced by 7x50 binoculars used from aircraft in the daytime is practically negligible.

Having investigated the two parameters R_m and C_o which occur in equation (7) we are now in a position to consider the probability that a given life raft will be seen. For doing this, we have available the search theory outlined in Section I, and the unassisted and simulated search sightings of reference (a). First of all, we would like to know whether or not equation (11) is of the correct form to give a reasonable representation of the probability of sighting the raft as a function of position along the aircraft track. Second, we are interested in knowing the extent to which the probabilities, predicted from laboratory data, are realized during service trials or, in other words, is the constant in the exponent of equation (11) correct. The unassisted sighting range data provide means of answering these two questions. The raft was always approximately on the aircraft track so that y and R are approximately equal and the probability considered is therefore P_o, that of seeing the target on track. The search doctrine employed was specific in that each observer carried out uniform scan over the forward 45^o of azimuth only, so that Θ in equation (11) is known. The same aircraft was used in all tests, its ground speed remaining approximately constant at 120 knots so that v in equation (11) is known. Before rewriting equation (11), we must introduce a factor f to take care of the possibility that the contact probability in unit time is smaller in service trials than it is under laboratory conditions. Making the various substitutions,

$$\left.\begin{aligned} P_o &= 1 - \exp\left\{-0.81fR_m\int_{R/R_m}^{\infty}\theta_o\, d(R/R_m)\right\} \\ Q_o &= e^{-0.81fR_m\int_{R_m/R}^{\infty}\theta_o\, d(R/R_m)} \\ -\log_{10} Q_o &= 0.35fR_m\int_{R_m/R}^{\infty}\theta_o\, d(R/R_m) \end{aligned}\right\} \qquad (12)$$

Now Q_o can be obtained from the assisted sighting range data in the following way. Let N_o be the total number of sightings opportunities in a particular set of data. Since no sightings were missed N_o is the total number of sightings in the set. Let N be the number of sightings for which the range is equal to or less than R. Then

$$Q_o = N/N_o \; ; \; -\log_{10} Q_o = + \log_{10} N_o/N \qquad (13)$$

Values of $-\log_{10} Q_o/R_m$ obtained from the various sets of data are presented in Figure 3. For comparison with these data, theoretical results were computed by means of equation (12). This was done in the following way. A mean value of 15% was taken for C_o. Using this value θ_o was computed by means of equation (7). This was plotted and the integration indicated in equation (12) was carried out with a planimeter for various values of R/R_m. Finally a value of f was selected which gave the best fit near R/R_m=1. The result of this calculation using f=2/3 is shown as the full line of Figure 3. Examination of Figure 3 shows considerable scatter among the various points. This results from two causes, first the number N_o for each set of data used was not large so that statistical fluctuations of considerable magnitude occurred. Second, the values of C_o for the various bearings relative to the sun were not all the same so that here again the various sets differ one from the other. At ranges less than 0.4 times the maximum most of the experimental points are below the theoretical curve. This results from the fact that whereas the target was always near track it was not necessarily on track so that for the shorter ranges y and R of equation (11) are not approximately equal. Hence, the trial data depart from the curve computed on the assumption that y and R are equal.

The value of 2/3 obtained for f is considered excellent. Considering such things as the fact that the scanning line is not as well defined in trials as in the laboratory that observer comfort in trials cannot compare with that in the laboratory and that aircraft windows become scratched and fogged over, it is surprising that f is as high as 2/3.

Having determined f, equation (11) with the appropriate constant in the exponent is integrated from $y/R_m = 0$ to $y/R_m = \infty$ for various values of x/R_m to obtain $-\log_{10} Q/R_m$ as a function of x/R_m. The results of these calculations are presented in Figure 4. They refer to uniform scan over the front 180° as carried out by 4 observers each being responsible for one 45° sector. With Figure 4 as a working curve P is obtained as a function of x/R_m for various values of R_m. These are presented in Figure 5. Twice the area under each curve, when multiplied by R_m gives the effective path swept. These are presented in Figure 6. The average values of R_m for the various life rafts are indicated in the figure. These are approximately the cross sun values.

It is easy to see that the probability of sighting a life raft, using parallel sweep search depends upon the thoroughness with which the search is carried out, i.e., upon the ratio of effective path swept and sweep spacing. The relationship between this ratio and the contact probability has been worked out quantitatively in reference (b). The results are reproduced in Figure 7.

The creeping line search data reported in reference (a) was done using a sweep spacing of 1.5 nautical miles. The target was a Mark IV life raft. The aircraft flew cross sun and most of the search effort was down sun. In all there were 19 runs with only 3 complete misses. The contact probability was 16/19 or 0.84. From Figure 6, the average effective path swept for the Mk IV raft is 3.3 nautical miles so that the ratio of path swept to sweep spacing is 2.2. From Figure 6, the probability of contact is 0.96 instead of 0.84. Conversely, from Figure (7) the effective path swept in test can be computed. This is 1.8 instead of the 3.3. obtained from Figure 6. The difference, it is believed, is due to the fact that in test, only one side of the track was thoroughly searched. A better scheme, therefore, is to arrange the legs of the parallel sweep search up and down sun so that both sides of the track can be searched cross sun.

III. LEARNED SIGNALLING MIRROR

The ranges with the learned signalling mirror are so long that the effect of haze cannot be neglected. Hence, instead of employing all the data, the present analysis is based on that set of 24 runs in which the meteorological visibility was constant and equal to 30 nautical miles. First examination of the individual runs brings out one striking fact: There is little dispersion among the ranges at which individual observers sighted the mirror. This indicates that if the mirror flash strikes the aircraft there is little chance that any observer will miss it. Such dispersion as exists among the various runs, therefore, must depend not on the chance that the aircraft see the aimed mirror, but upon the chance that the life raft see the aircraft and aim his mirror correctly.

The runs were head on so that the raft was essentially on the aircraft track. The quantity $-\log_{10}Q_o = \log_{10}N_o/N$ was computed as in Section II and the results are presented as curve A of Figure 8. For a comparison with this curve a theoretical one has been computed for what one might reasonably expect of a lookout in a life raft as regards sighting an aircraft. This curve presented as B of Figure 8 was computed in the following way. The area and intrinsic contrast of a PBM aircraft seen head on are approximately known. The values are A=375 square feet and C_o=50%. Using these two values and the meteorological visibility which was 30 nautical miles, R_m was computed, the value obtained being 11 nautical miles. θ_o was then computed from equation (7) and the integration indicated in equation (11) was carried out. In order to obtain $-\log_{10}Q$ from the integration it is necessary to know the sector scanned and the effectiveness of the search. The approximate direction from which the aircraft was to approach was known to the observer but hardly with sufficient accuracy to justify reducing his scanning sector below 90^o. Hence, 90^o is taken as a reasonable value for Θ in equation (11). Considering the fact that the man in the life raft must keep afloat, keep track of the relative bearing of the sun and his circumstances as regards

comfort are not of the best, he should not be expected to carry out a search as efficient as that realized by an aircraft lookout. For our present purposes we will consider his search efficiency as half that of an aircraft lookout. With these two estimates as to expectations, curve B of Figure 8 was computed. A comparison of curves A and B shows that the two curves are roughly parallel but that A is displaced relative to B. One probable reason for this displacement is the fact that time is required, after sighting the aircraft, to focus the mirror on the aircraft.

IV. DYE MARKER

With the dye marker there are three variables in addition to those already encountered. The dye lies flat on the sea surface and hence, is a Case II target. Its projected area is a function of the altitude of the aircraft. The dye is dispersed in two ways; it gradually diffuses out, and it is mechanically dispersed by the motion of the sea. Average range is employed as an index for studying the effect of these last two variables. The variation of average range with order in which the run was taken was investigated for sea states 2, 4, and 6. The general shapes of the curves obtained were about the same indicating that time in the water is more important than sea state in dispersing the dye. Further trials are needed for sea states in excess of 6. All these ranges have been averaged and the results presented in Figure 9. The approximate time of the dye in the water is given for each run order. It is clear from the figure that the average range increases up to about 18 minutes and then decreases, the range at the end of an hour being about half the maximum.

There were no assisted sightings made with the dye marker. Furthermore, no figures are available concerning the area and intrinsic contrast of dye marker. Hence, the maximum range can neither be determined directly from assisted sighting ranges nor computed from area and intrinsic contrast. Approximate values of the maximum range were obtained by plotting $\log_{10} N_o/N$ for each set of data and estimating the position of the foot of the curve. These values are presented in Figure 10 in the form suggested by equation (6). Various values of target area and intrinsic contrast were tried in order to obtain a plot of equation (6) which best fit the data. The solid line in a plot of equation (6) using $C_o = 33.5\%$ and $A = 1.1(10^4)$ square feet. This line is a reasonably good representation of the data.

Because of the fact that the dye marker is an entirely different type target from either a life raft or an aircraft it was considered desirable to carry out a check to see whether or not the probability of sighting it agreed with theory. This was done by examining $-\log_{10} Q$ as in the other sections. Because of the fact that the range depends upon the time the dye marker is in the water, attention was confined to only run order, one altitude and one meterorological visibility. There were sufficient data available from the B order, altitude 300 feet, meteorological visibility 8 miles to obtain a $-\log_{10} Q_o$ curve. This is presented in Figure 11. The solid line is computed. In view of the uncertainty in the maximum range, the agreement between theory and trial data is considered satisfactory.

V. OTHER TARGETS IN REFERENCE (a)

There are a number of targets in reference (a) which have not been considered here. The reasons for their omission here are as follows: In some cases the data available is insufficient to permit analysis. Some of the trials were night runs for which the theory has not yet been developed. There is considerable need for laboratory data and theory for use with trial data in solving problems of night search and signalling. Some of the trial data involves the combined probabilities of sighting by life raft and by aircraft. Analysis of these data require additional information with regard to search doctrine and efficiency of life raft lookouts.

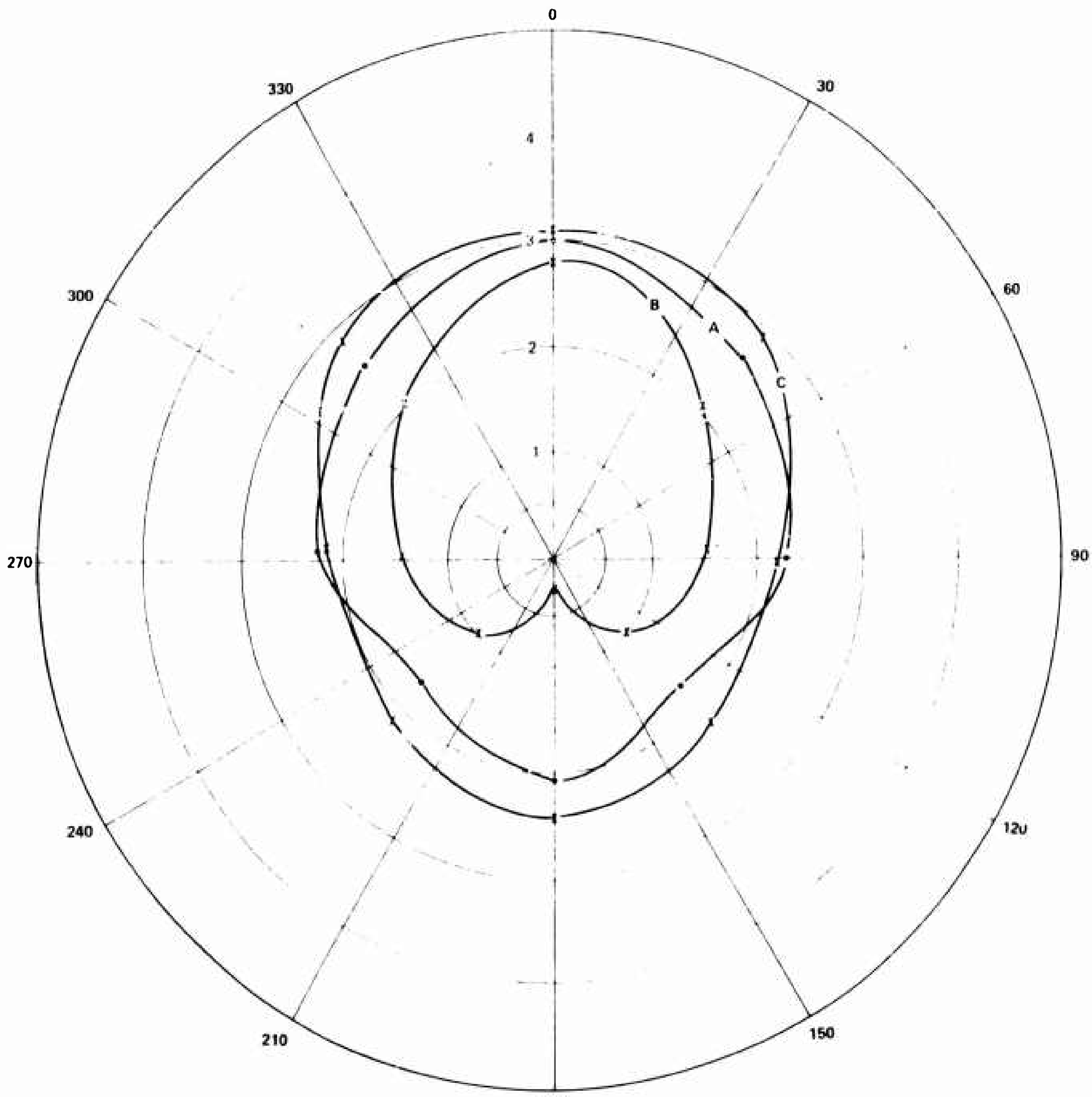

FIGURE 1

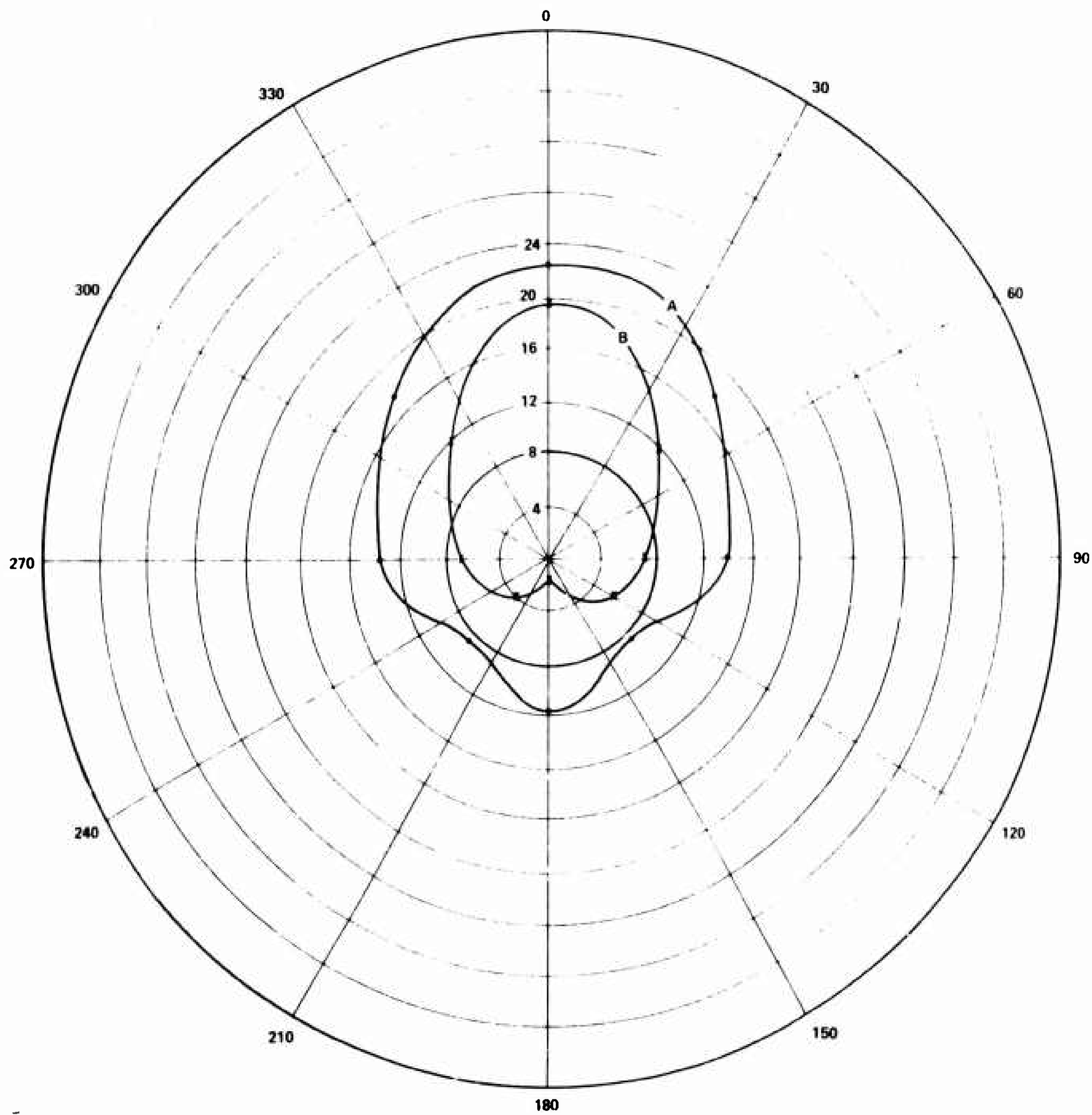

FIGURE 2

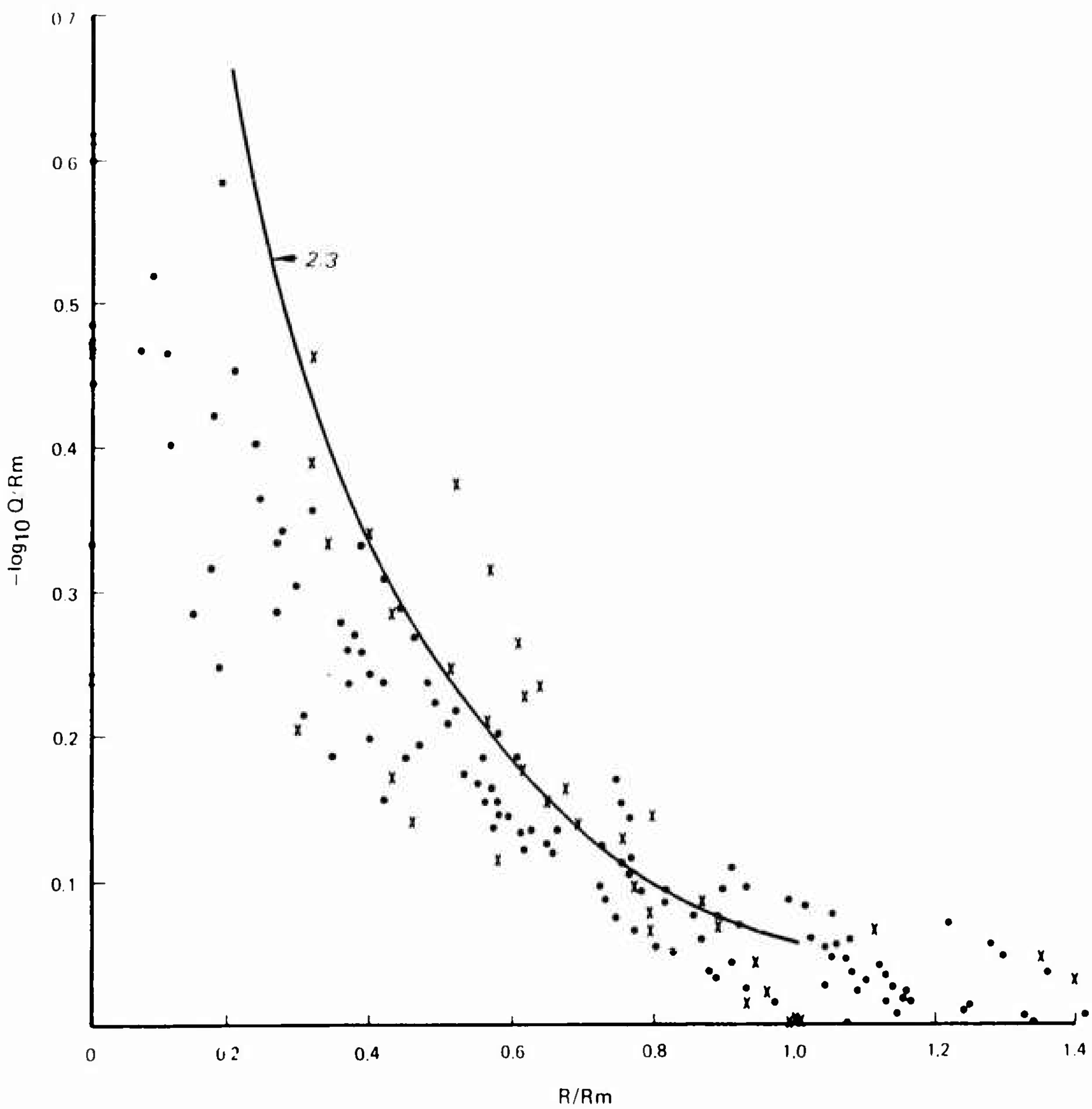

FIGURE 3

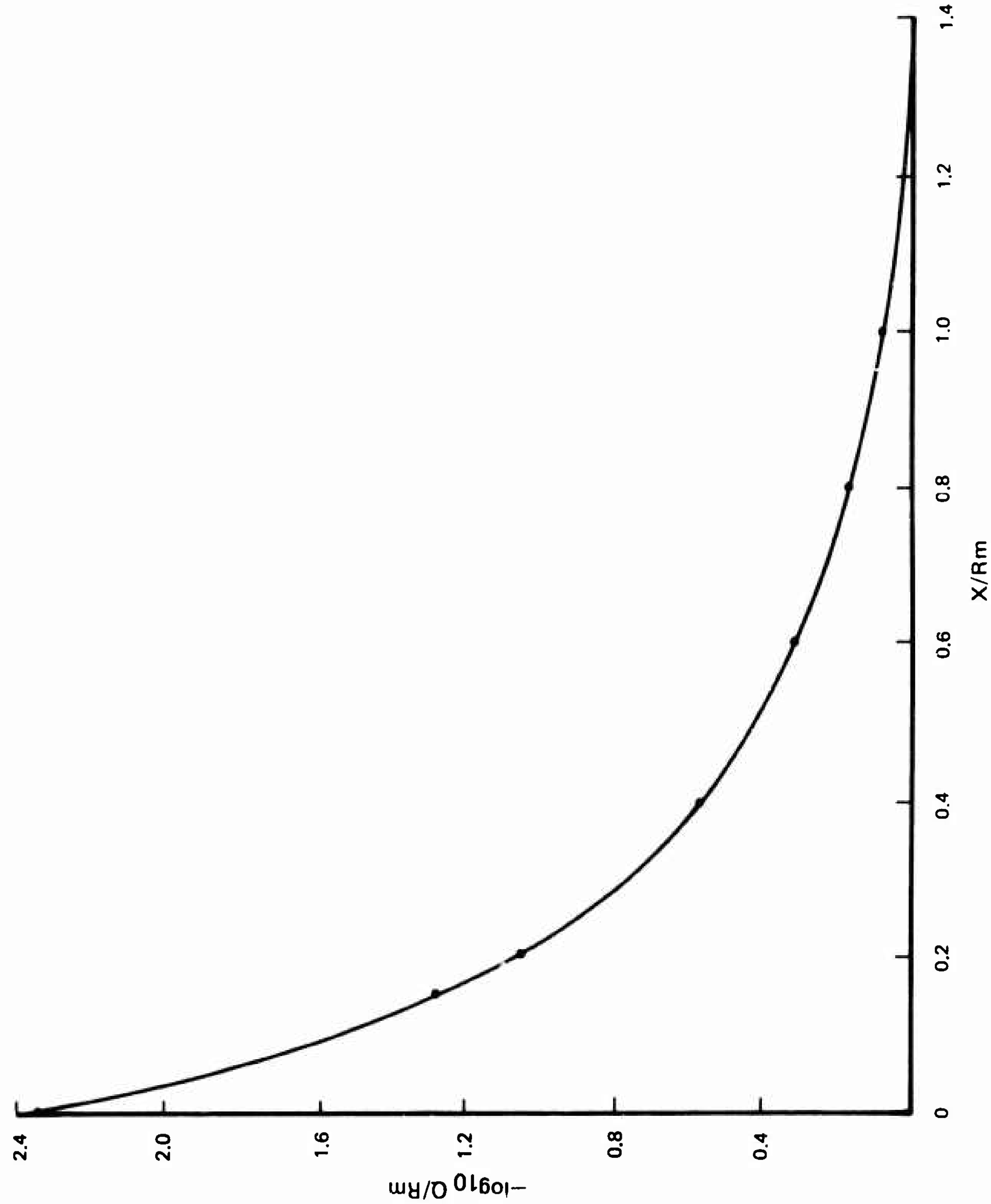

FIGURE 4

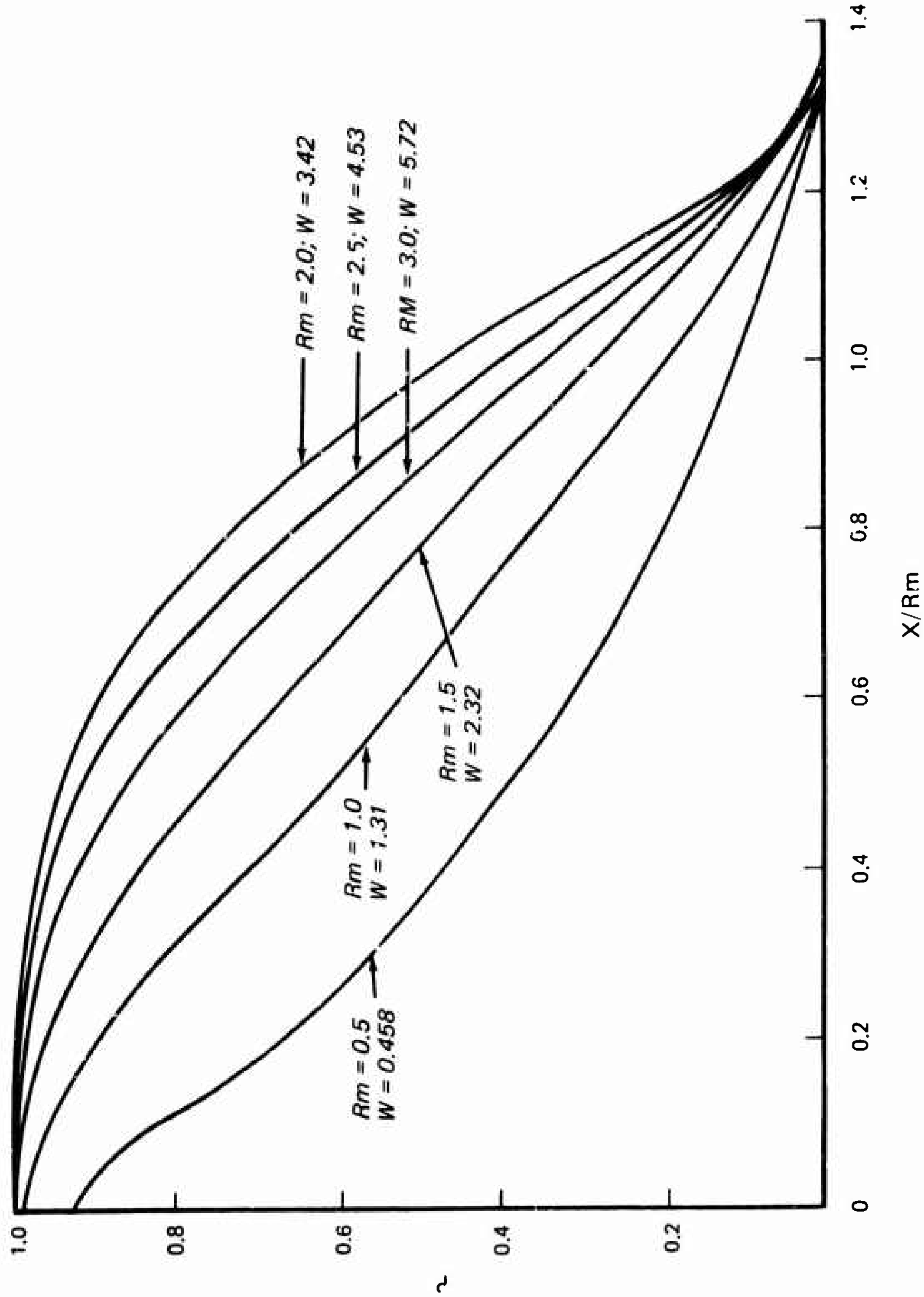
Rm = 2.0; W = 3.42
Rm = 2.5; W = 4.53
RM = 3.0; W = 5.72
Rm = 1.5
W = 2.32
Rm = 1.0
W = 1.31
Rm = 0.5
W = 0.458
1.0
0.8
0.6
0.4
0.2
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
X/Rm

FIGURE 5

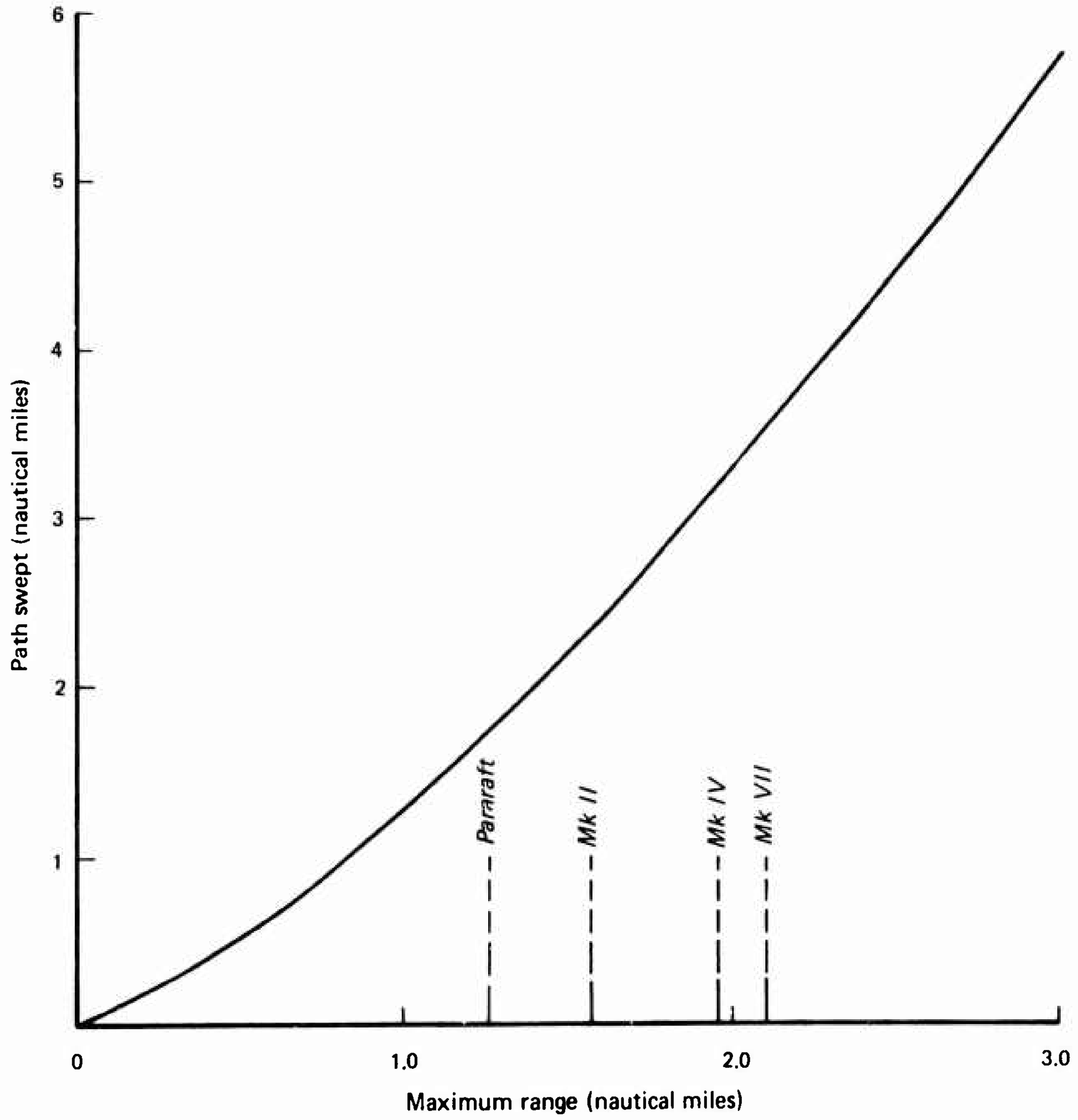
Path swept (nautical miles)
0
1
2
3
4
5
6
1.0
2.0
3.0
Maximum range (nautical miles)
Pararaft
Mk II
Mk IV
Mk VII

FIGURE 6

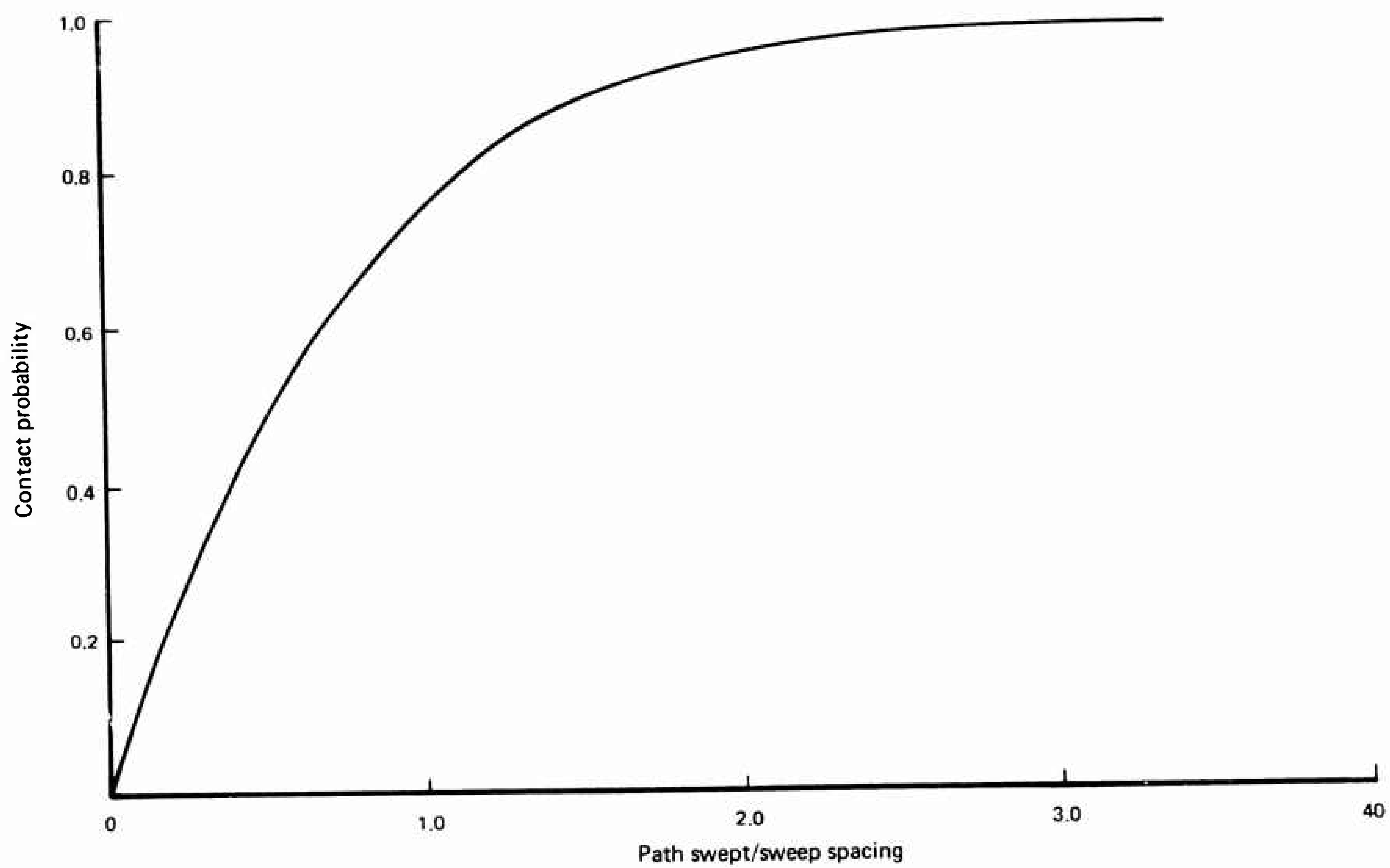
1.0
0.8
0.6
0.4
0.2
Contact probability
0
1.0
2.0
3.0
40
Path swept/sweep spacing

FIGURE 7

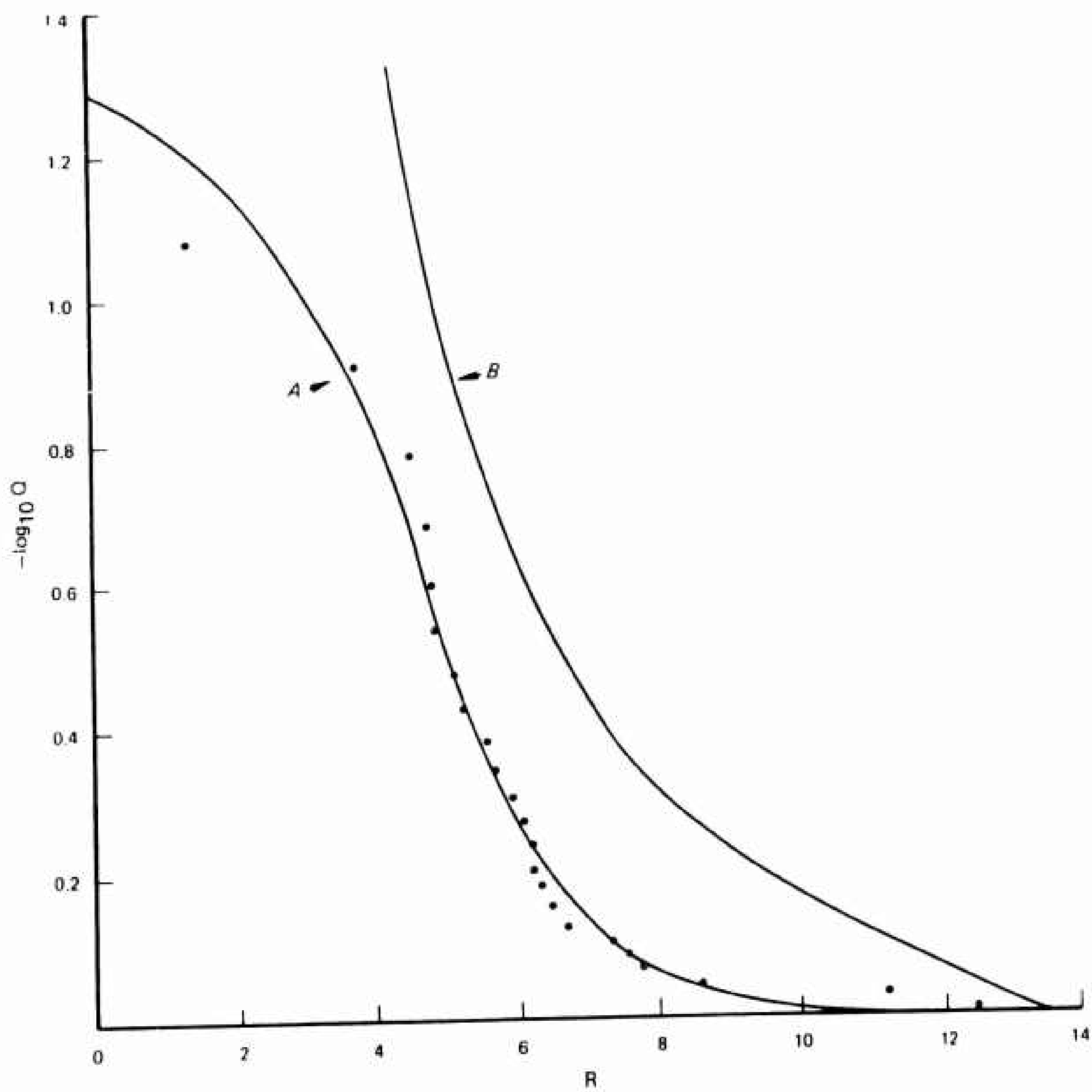

FIG. 8: MIRROR – V = 30

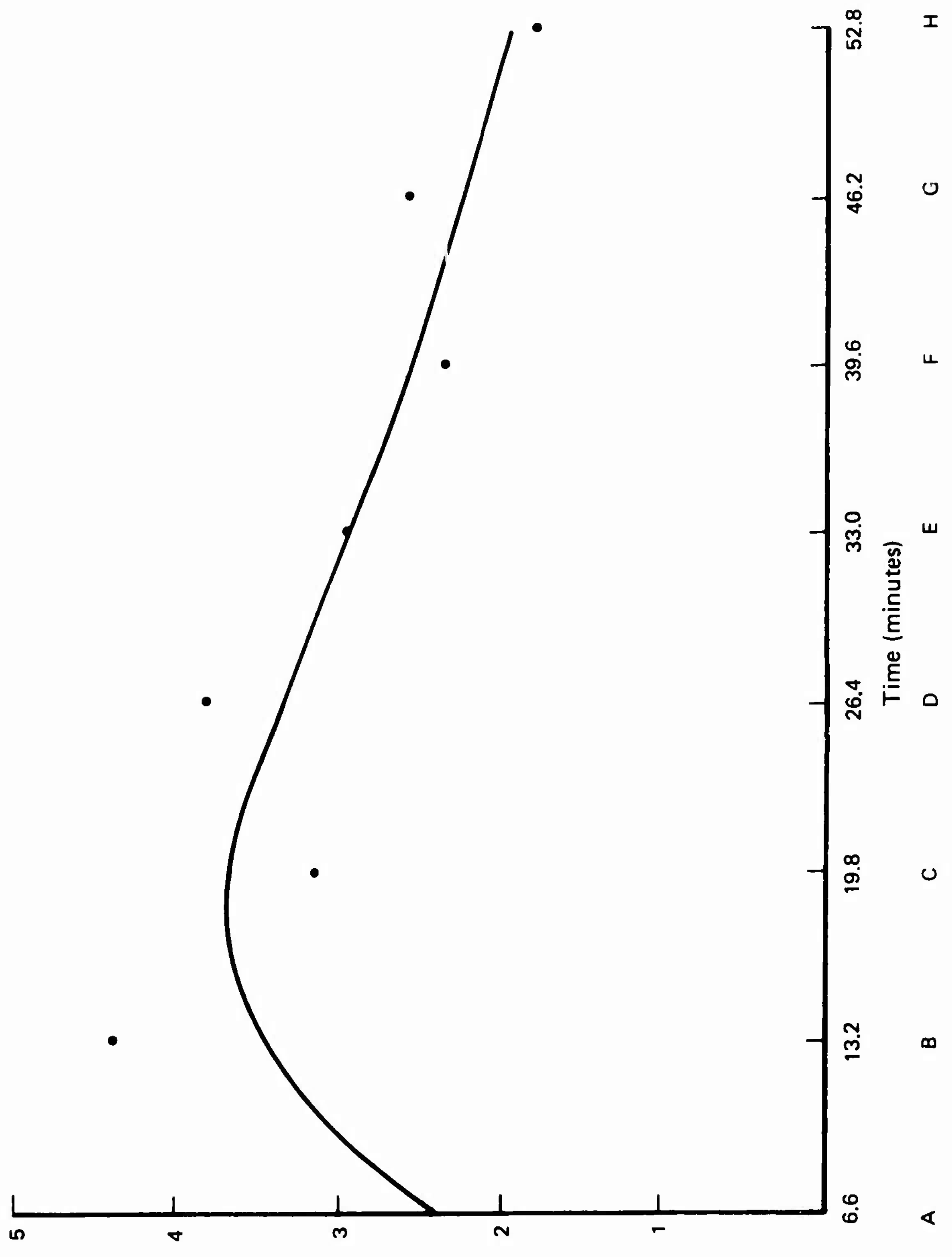

FIG. 9: DYE MARKER

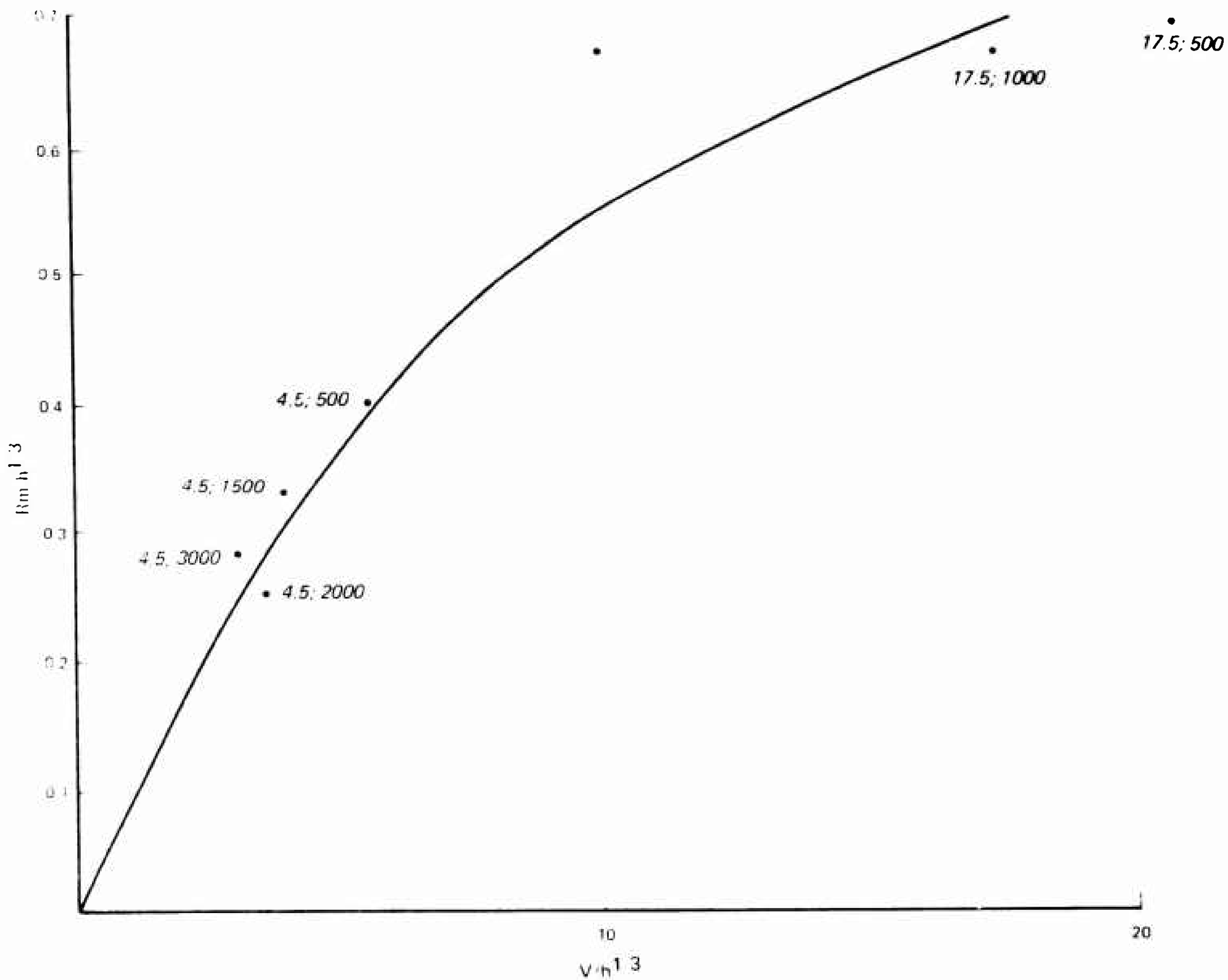

FIG. 10: DYE MARKER $C_o = 33.5$ $A_o = 1.1\ (10^4)$

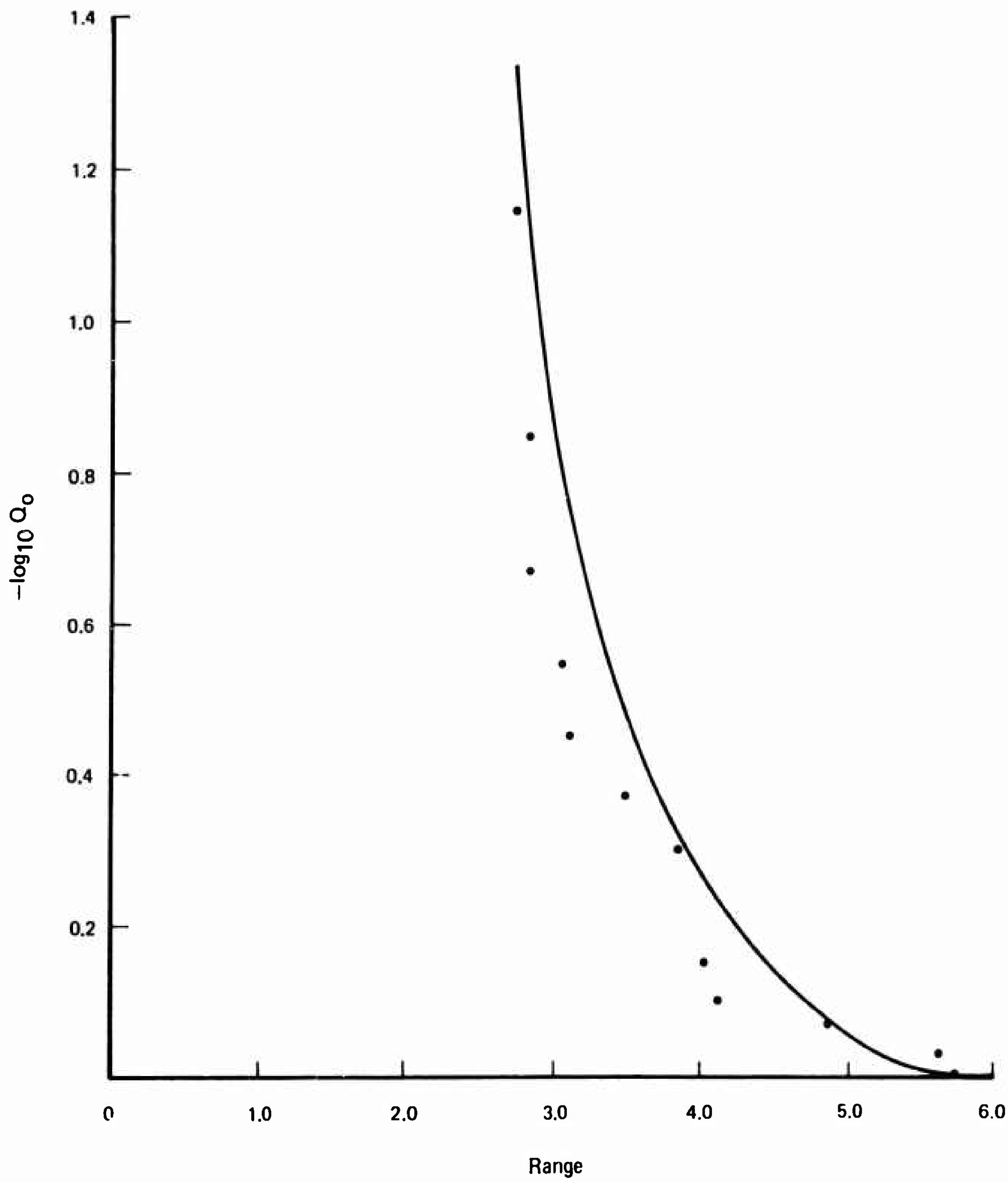

FIG. 11: DYE MARKER

REFERENCES

(a) Preliminary Report TED No. UNL-25159 with appendices I to III incl., 7 May 1945.

(b) OEG Report 56, "Search and Screening", 172 pp., Unclassified, 20 February 1947, AD 814 773.

(c) K. J. W. Craik "Naked-Eye Spotting of Low Flying Aircraft from the Ground by Day" - Medical Research Council. "Naked-Eye Scanning by Day with Special Reference to Observations from Coastal Command Aircraft" - Physiological Laboratory, Cambridge.